

# Internal decoherence and related phenomena

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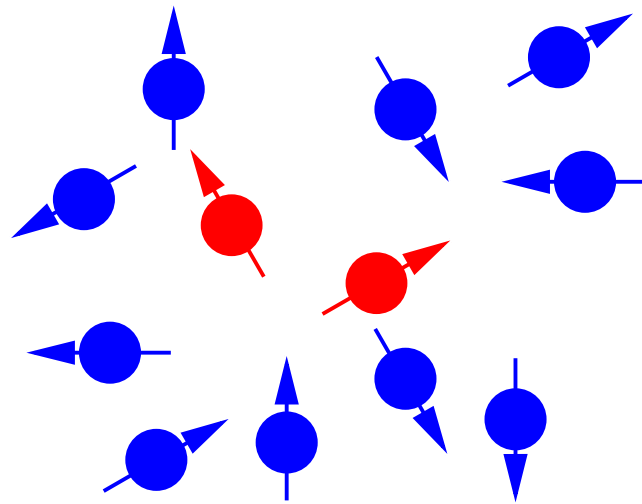
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Workshop of the DFG research unit 2692  
The internet, 23 September 2020



# Context



Investigation of **decoherence of a subsystem** if the combined system (including bath) is evolved via the time-dependent Schrödinger equation.

Employed measure of decoherence: reduced density matrix

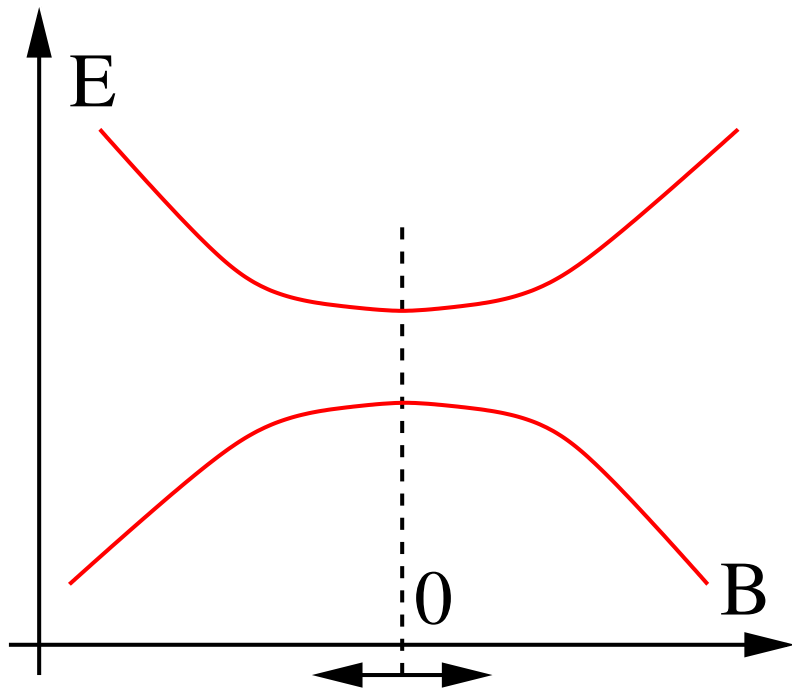
$$\tilde{\rho}_{\text{system}} = \text{Tr}_{\text{bath}} \left( \tilde{\rho} \right)$$

Other options and details, see M. Schlosshauer, Phys. Rep. **831**, 1-57 (2019)

## Goal

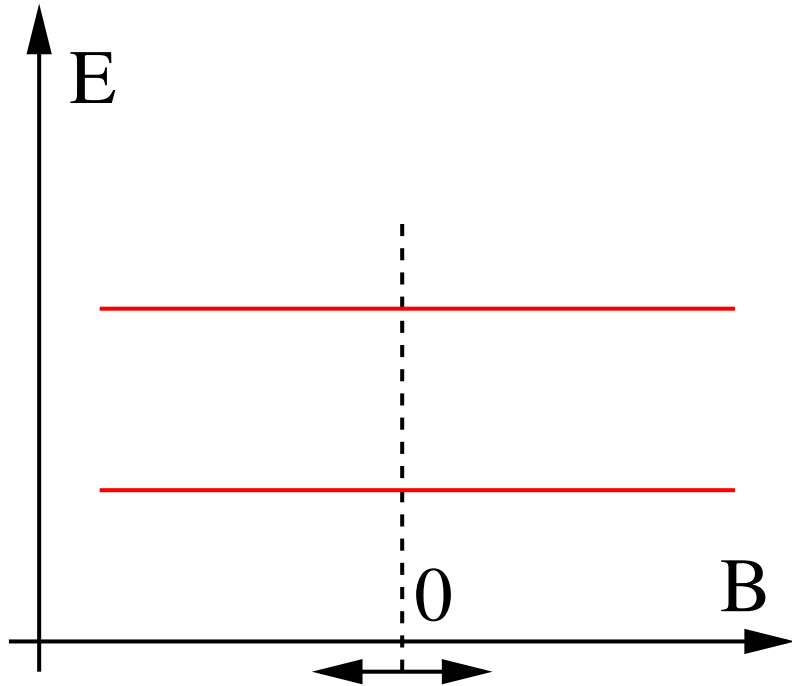
Find systems  
which decohere slowly.

## Clock transitions



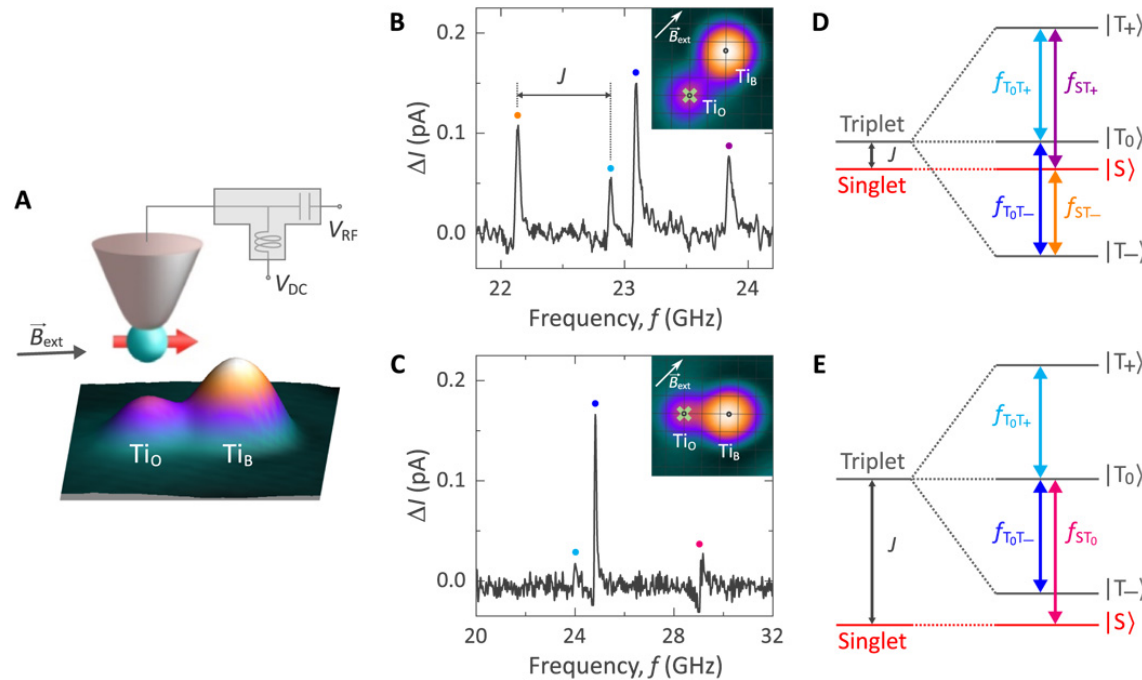
Fluctuations produce little effect on system spins since  $\Delta E$  of transition is independent of field at  $B = 0$ , at least to some order of a Taylor expansion.

# Perfect clock transitions



Fluctuations produce little effect on system spins since  $\Delta E$  of transition is *totally* independent of field.

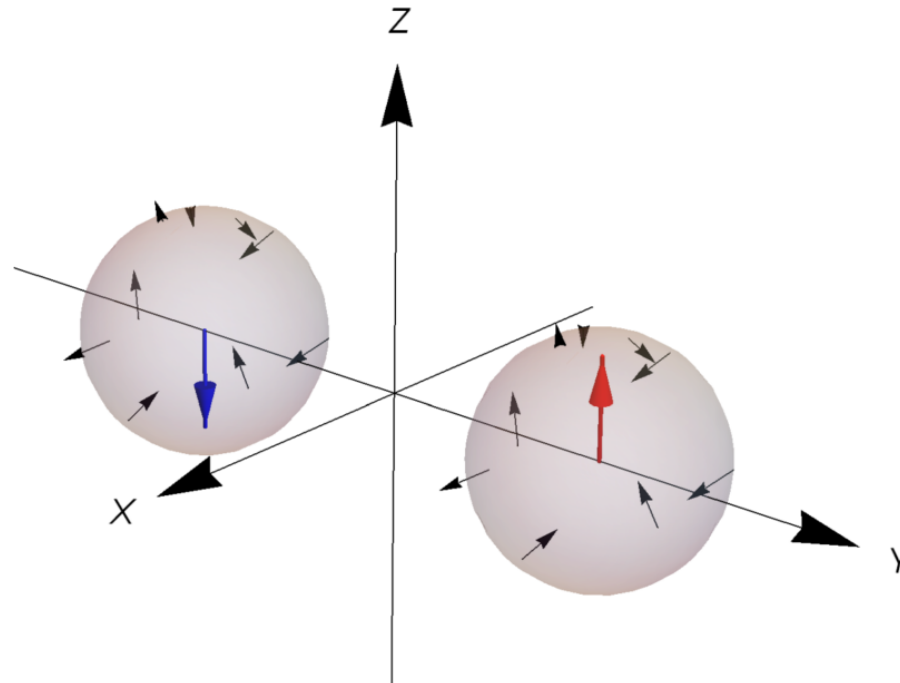
# Experimental realization



Dimer of two spin 1/2:  $\Rightarrow$  singlet and triplet levels

Y. Bae, K. Yang, P. Willke, T. Choi, A. J. Heinrich, and C. P. Lutz, Science Advances **4**, eaau4159 (2018).

# Decoherence of clock transitions I



Bath: electronic or nuclear spins.

Interactions: system-environment, but also among environment spins – dipolar.

$$\tilde{H} = \tilde{H}_S + \tilde{H}_{SE} + \tilde{H}_E$$

P. Vorndamme, J. Schnack, Phys. Rev. B 101, 075101 (2020)

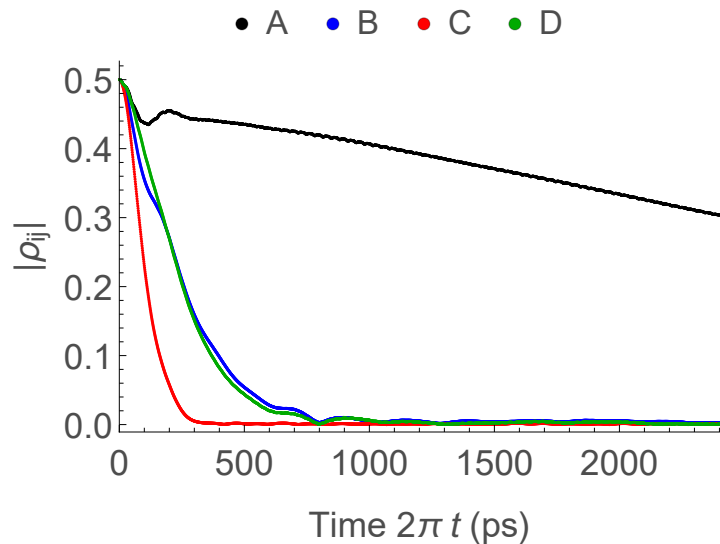
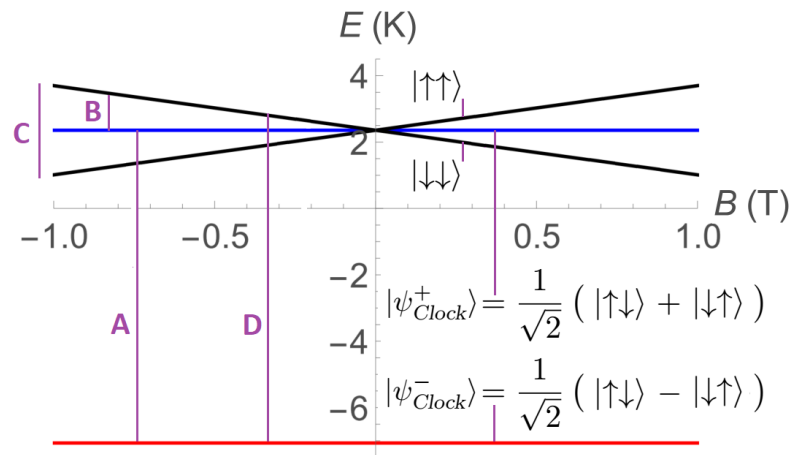
# Decoherence of clock transitions II

Solution of the TDSE with initial superposition states A, B, C, D:

Clock transition A decoheres more slowly than any other transition under all circumstances.

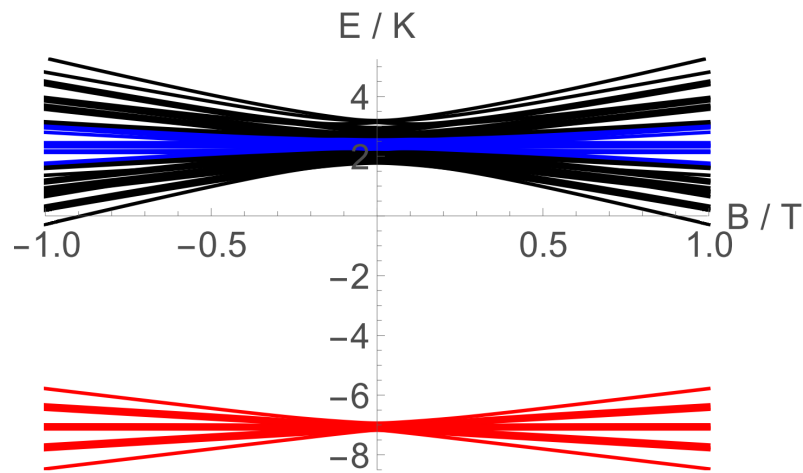
Ratio of system-bath and bath-bath interaction seems to be important.

P. Vorndamme, J. Schnack, Phys. Rev. B 101, 075101 (2020)





## Decoherence of clock transitions III



Single-particle/mean-field picture only valid for small couplings to a few bath spins.

Initial product state entangles in the course of time. Eigenstates of the full Hamiltonian loose clock property.

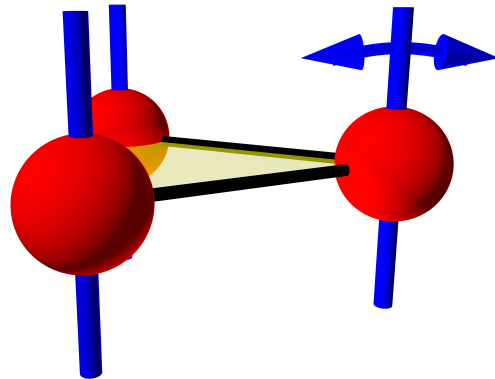
P. Vorndamme, J. Schnack, Phys. Rev. B 101, 075101 (2020)

## Related

System of  
spins and phonons.

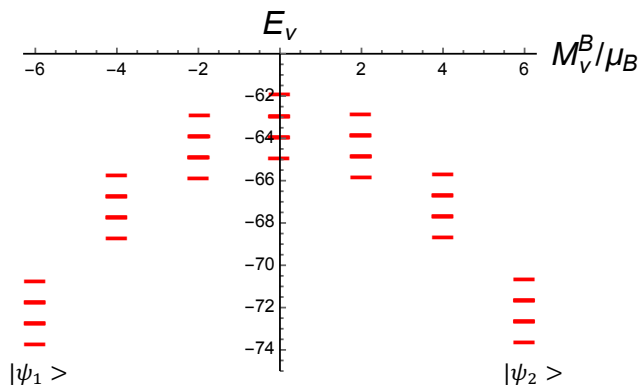
# Spin-phonon system I

Phonons couple to easy axes of system and turn collinear into non-collinear anisotropic spin system.

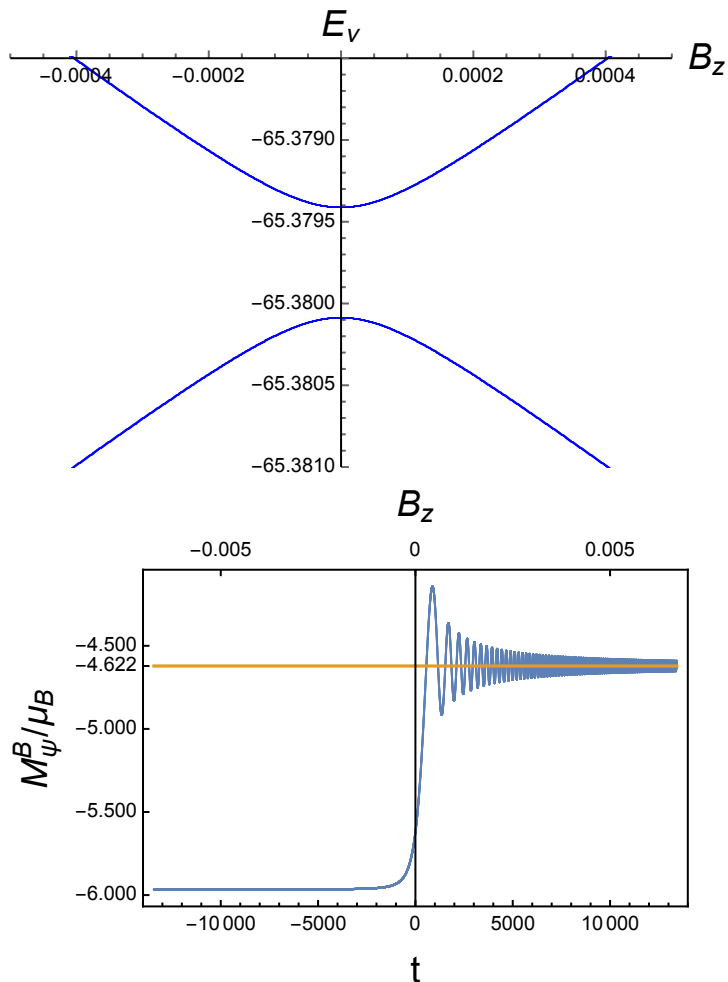


Time-evolution of spin-phonon system via time-dependent Schrödinger equation (phonon basis truncated).

Example:  $N = 3$ ,  $s = 1$ , ferro, and 3 harmonic oscillators, one for each spin.



## Spin-phonon system II



Phonons turn level crossing into avoided level crossing.

Spin dynamics modified in a fundamental way: Landau-Zener tunneling.

Zero-point motion of phonons suffices for the effect.

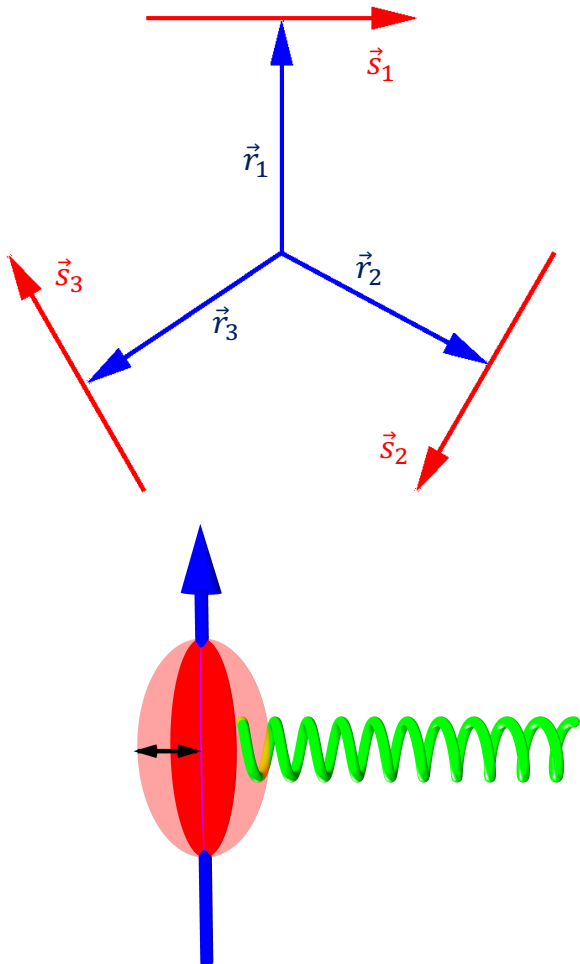
K. Irländer, J. Schnack, Phys. Rev. B **102** (2020) 054407

# Outlook: other robust systems

Toroidal moments.

Purposely designed spin-phonon interactions.

K. Irländer, H.-J. Schmidt, J. Schnack, arXiv:2006.16575



# Students make the science go round



Patrick Vorndamme



Kilian Irländer

Thank you very much for your  
attention.

The end.

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